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Fuzzy Logic and Optimization of Educational Paths

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Abstract: In our work we analyze a set of economic factors, which affect on student's decision of educational path change. Taking into account such factors as the expected salary after graduation, educational costs, set of government exams and the amount of educational paths in the university, we estimate the possibility for each student to optimize his personal educational path. To describe the behavior of a rational individual and to estimate the optimal and preferred educational path under these conditions we use the classical economic theory, the classical theory of economic behavior, the methodology of increasing efficiency of the human capital and the institutional economic theory. To describe the economic motivations of an individual by changing the educational path we developed a mathematical-economic model of optimization and tested it on real data on more than 5,3 thousand students. It is necessary to highlight that, mainly, the choice of an educational path by a rational individual is driven by economic motivations and by his knowledge on the expected earning level after the graduation. In our model we compare the educational paths, which were chosen by students and take into account the importance of personal expectations to set and calculate the optimal, from the point of view of economic rationality, educational path, which is compared with current student's educational path. According to the modeling results, 66% of all students have chosen their optimal educational path taking into account their economic preferences and personal skills. To estimate the possibility for each student to change his educational path we developed an approach, that is based on the fuzzy logic model of Mamdani type. According to this approach, the possibility of educational path change for a student is calculated on the panel data taking into account the amount of perspective directions of student's graduation and educational paths, the possibility of budget support of the graduation and the expected salary level after graduation. As the application of this approach we can estimate the probability of educational path change for each student and optimize the education process in the University.

Keywords: modelling theory, fuzzy logic, optimization methods, mathematical economic modeling, systems behavior, higher education system, educational paths, behavioral economics, economic expectancies.

1. INTRODUCTION

Last tendencies in the global educational system and the increasing competition in the field of higher education represent a big challenge for Russian universities. According to such rating systems as QS and THE, Russian education system has a fewer amount of finance and labor resources than its competitors represented by worldwide known universities. The optimal use of university's resources in this competition requires a comprehensive analysis of the student's motivational factors and a deep analysis of financial effectiveness and energy efficiency in the organization of higher education. In this article we focus our research on the problem of educational process optimization, depending on the labor market demand and the student's personal expectancies. The choice of a university and an educational trajectory determines student's current and future personal well-being.

At the same time, the choice of an educational path, made by each student, impacts on the further development of economic sectors. In this article we analyze student's economic motivation in the context of individual behavior theory. The choice of an educational path depends on a set of economic factors, such as tuition fees, available scholarships, and the expected income after graduation. It is necessary to highlight, that in conditions of budget support absence, the question of education recoupment for students is very important, and taking into account the data from an sociological survey the recoupment period for students should be two years. So, the expected salary after the

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graduation is one of the main factors, when choosing the educational trajectory.

Throughout the time period from 2004 to 2014, a significant increase in the average monthly salaries level was observed. A similar behavior was observed for the price of higher education (Gurban I.A., Tarasyev A.A., 2016). For the time period from 2004 to 2013 the curve of wages in the manufacturing sector was similar to the price curve for higher education (M. Carnoy, I. Froumin, P.K. Loyalka, J.B.G. Tilak, 2014), but since 2013 we can observe a discrepancy in these indicators. This phenomenon can be explained by the fact that the price of tuition has increased by 74% since 2013, while the average monthly salaries level increase was only by 38%. In the area of financial activity, the time series of tuition prices are similar to the time series of wages in the fields of health and education from 2004 to 2008 (V.A. Koksharov, G.A. Agarkov, 2015).

2. RELEVANT LITERATURE

According to the classical theory of individual economic behavior, student's decisions have to be based on the considerations of clear rationality. It is assumed that individuals choose the best way to maximize the utility of the obtained benefits or to search a job with the best possible future income. Along with this, it is understood that people are able to evaluate all the possible choices and understand the consequences of each option (Gerard Debreu, 1956).

Behavioral economists assume that people react differently to equivalent situations depending on their own estimates, whether they lose or win. Pursuant to the classical theory of individual economic behavior, decisions of rational individuals are based on the considerations of clear rationality. Individuals choose the best way to maximize the benefits obtained or search a job with the best possible future salary level. In terms of the theory of modern institutional economics we assume that the economic behavior of the individual is largely determined by the limitations of the institutions (G.M. Hodgson, 2003).

Modern Institutional Economics Theory argues that the economic behavior of the individual is largely determined by the constraints imposed by institutions (Geoffrey M. Hodgson, 2003). The study of economics of higher education and, in particular, the economic analysis of the preferences is seen as an urgent task of researchers. Several mathematical models have been developed based on an analysis of the career choice (Keane M.P. & Wolpin K.I., 1997).

The study of economics of higher education and, in particular, the economic analysis of the preferences, is seen as an urgent task of researchers. Questions of student's economic expectations and university's entrants are widely discussed by contemporary economists. In particular, the dependence of the expected incomes after the graduation on different specialties is under investigation (J. Jerrim, 2015).

It is clear that the educational choices made by young people, are largely influenced by both the education system and public finance sector as a whole. Also we wish to highlight that this influence has a significant national distinctiveness (M. Carnoy, I. Froumin, P.K. Loyalka, J.B.G. Tilak, 2014).

Economists can trace the interdependence of the different characteristics of students and the financial implications of their higher education degrees (Bachan R., 2014). At the same time, various aspects are considered, for example, students' awareness of the available concessional lending when taking up a loan (Booij A.S., Leuven E. & Oosterbeek H., 2012). In our study, we adhere to the classical economic approach.

Relevant data were reported by Beffy M., Fougère D. and Maurel A. for modeling the determinants that influence college choice. Decision model training was implemented in three phases, focusing on the significance of the educational paths choice with respect to expected income. Results of the analysis indicate that, according to French education data, non-monetary factors are considered as key aspects that define the choice of a major. In the analysis of the factors that determine college dropout, Eckstein Z. and Wolpin K.I. concluded that there is a connection between successful educational paths and students' economic expectations. Students with lower expected returns compared to their classmates, leave college more often without obtaining a diploma. Given the advantages of the individual business education diploma for the international recruiters, some researchers oppose the method of financial interpretation of costs and benefits of business education to the holistic approach based on the concept of "internal" and "external" career success (Kuznetsov A. and Kuznetsova O., 2011). At the same time, they shift the focus towards a precedence of social values.

In our study, we adhere the classical economic approach. The state of the Russian higher education provides extensive statistic data to analyze the impact of economic incentives on human behavior. In short, the situation can be characterized following sentences: the government creates incentives for learning technical and natural sciences by providing a wide spectrum of tuition subsidies and state scholarships; the state and independent experts report about the “overproduction” of the humanities graduates (economists, students of law, managers); young people show a preference for a liberal arts education (W. Lutz, J. Crespo Cuaresma, W. Sanderson , 2008), despite a lack of available scholarships (Ch. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, 2016); the system of the Unified State Examination (the USE) allows to formalize and to analyze the “set of opportunities” for university applicants in the search of a major.

3. EDUCATIONAL PATHS MODELING

The dynamic model for an analysis of the life-cycles, the educational and professional choices, which we introduce in this article, significantly expands the view of the efficiency of human capital investments. Based on the life cycle of young people, the model also makes a reasonable forecast of future professional choices and size of their further income.

The state of affairs makes it possible to examine how the students’ preferences are economically feasible. The students’ preferences were compared to the optimal,

economically feasible educational choices, calculated from the facts mentioned above to estimate the value of economic expectations of a rational individual. The econometric methods are often used to study the relation between individuals' educational paths and economics of education (Meghir C. & Rivkin S., 2011), but we used a specially established econometric model.

To establish an an econometric model of higher education optimization we analyzed a dataset describing the educational paths. We denote the Unified State Examination (the USE) marks submitted to the university selection committee as e_s, where the value $s \in \overline{1,m}$. Here the parameter m denotes the numbers of required exams at the final matrix Q. In the case, when the exams are not required we denote e_s equal to zero, $e_s = 0$, $s \in \overline{1,m}$.

The enrollment marks corresponding to the chosen speciality $k \in \overline{1,l}$ are determined by parameter ov_k for paid tuition, and by the parameter ob_k for the budgeted tuition, $ob_k < ov_k$. Here parameter l denotes the number of specialities for the final matrix Q.

The matrix Q describes the set of exams required for the chosen specialities. Coefficients q_{ks} of the matrix Q are given according to the following rule: $q_{ks} = 1$ if examination s should be presented for speciality k; $q_{ks} = 0$ if the examination s is not required for the speciality k.

The parameter c_k denotes a tuition fee for the speciality k, considering the overall cost for the whole education period. The parameter cv_k stands for student's education costs in speciality k: $cv_k = 0$ if a student's educational path allows for budgetary funds, and $cv_k = c_k$ if tuition requires payment, $k \in \overline{1,l}$. The parameter w_k means the expected income of a student over the two-year working period following the exit from the university.

To estimate the value of optimal educational paths in respect of economic rationality, the above mentioned data are processed with software support, implementing a possible educational path search algorithm (considering the limitations for the USE results and the set of exams for the major). Then the education path is searched, which shows an optimal discrepancy between tuition costs and expected income after the graduation. At this modeling step we analyze the economical cost of a student's education process, where $cv_k = 0$ if student's educational path takes into account budgetary funds, and $cv_k = c_k$ if student's tuition requires payment. In these conditions we need to maximize the gap $y_k(t)$ between the expected students salaries level after the graduation and the education costs for every academic year t:

$$y_k(t) = w_k(t) - cv_k(t) \xrightarrow[k]{} \max, \qquad (1)$$

where the parameter $w_k(t)$ for the speciality k is the expected income of a student over the two-year working period following the exit from the university; the parameter $cv_k(t)$ denotes student's education costs for education process, estimated for the year t, $t \in [0,T]$, in the period T of education.

At the same time we have to take into account following conditions by determining the capacity of budgetary funds aimed at higher education:

$$\sum_{s=1}^{m} e_s \cdot q_{ks} \le ob_k \Rightarrow cv_k = 0, \qquad (2)$$

$$\sum_{s=1}^{m} e_s \cdot q_{ks} \le ov_k \Rightarrow cv_k = c_k. \qquad (3)$$

Here q_{ks} are coefficients of the matrix Q; $k \in \overline{1,l}$ and $s \in \overline{1,m}$. As the result we will see the possibility of free costs for the student's education process and estimate possible alternative educational paths for every student during the period of education.

4. MODELING RESULTS

The developed econometric model was calibrated and tested on the statistical data of educational paths for the set of 5,313 thousands individuals (including 2,113 thousands students who paid the expenses and 3,400 thousands students with the budgetary subsidies), who entered the university in 2013. As we mentioned in this model, a large number of educational opportunities is available to the students within the assigned amount of the exams (the USE) they passed on leaving school. The selected set of exams serves as a personal preference (for example, interest in the humanities, natural or technical sciences) and complies to the requirements of society and the government.

To determine the optimal educational path in terms of economic conformity we applied the above presented search algorithm. It included data on the students' USE marks, submitted to the selection committee, information about entrance marks for fee-paying students and government subsidies, the tuition fee data, and expected income in the chosen field during the working period of two years following the graduation from the university. It is necessary to highlight, that according to the sociological survey the recoupment period of graduation fees for students should be less than three years. Subsequently, the optimal paths were correlated with the applicants' choices.

We believe that one of the most important practical conclusions from the study of optimal educational paths should be the consideration of the applicants and the students' expected incomes in the process of giving state assignments in higher education. Many fields of study indicate nonoptimal educational trajectories by saving on the costs of education and the discrepancy within the expected income. Assessment of the relationship between the selected cost-optimal ways of education and academic motivation (Table 3) is undoubtedly

of interest. We evaluated academic motivation in terms of the percentage of students dropped out after one academic year spent on the selected speciality.

Table 1 Correlation between economically optimal educational paths and academic motivation.

Fields of study	Percent of individuals with optimal choice, %	Percent of students dropped out after first academic year, %	The USE mean mark
1. Economics and Management	71.46	9.23	245.59
2. Public Administration and Entrepreneurship	73.40	9.57	244.71
3. Humanities and Arts	53.03	14.65	256.81
4. Natural Sciences	53.89	23.32	204.79
5. Mathematics and Computer Sciences	76.92	24.18	228.78
6. Material Sciences and Metallurgy	36.76	17.84	180.33
7. Mechanics and Machine Building	52.76	13.47	195.45
8. Radio electronics and Information Technologies	78.42	19.18	203.55
9. Social and Political Sciences	58.63	10.84	240.98
10. Civil Engineering	91.97	17.88	226.60
11. Power Engineering	75.53	14.73	201.08
12. Physics and Technology	71.95	23.10	207.55
13. Physical Education and Sport	72.00	9.33	238.18
14. Fundamental Education	73.33	20.00	213.21
15. Chemical Technology	83.96	25.13	218.2
16. Military Technical Education and Security	71.59	7.95	201.34

In order to assess the impact of learning ability and school education for admission to the university, we also considered the individual's mean school marks. It is interesting, that the choice of cost-optimal education paths has little influence on academic motivation, and the drop-out rate among students who have chosen some of the economically optimal field of research has reached a maximum value. With regard to Table 1, it can be concluded that a small percentage of dropouts among students may be assigned to individual's high school marks, rather than to the percentage of students who selected the best educational ways. This implies the importance of personal characteristics as the raising educational factor.

5. FUZZY LOGIC FOR EDUCATIONAL PATHS

To establish the probability of a student changing of educational path, a fuzzy logic model of Mamdani type was developed according to the following parameters. 3 input rules converge into establishing the output variable of probability of change. In this way the number of possible perspective directions are the first variable that affect in the decision of a student changing of program, the second variable is the probability that these students have to get budget support from the government or university to pay for their studies, and lastly the last variable is an estimate of the amount of money the students will earn as a salary when they graduate from their current program. The following step to the model is to establish the ranges that can represent through natural languages each one of the variables of the model.

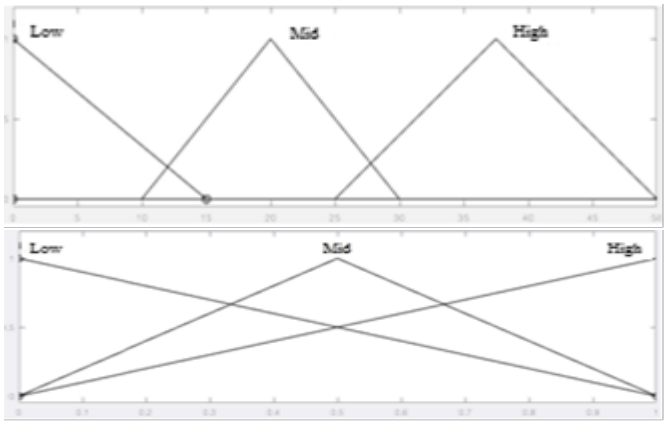

Fig. 1. Perspective Directions and Budget Support membership functions

This process is made through an analytical revision of the circumstances of the environment in which the model will be applied. For this picture (Fig. 1) there are only three ranges (low, mid and High) but the difference is that each range is bigger than the previous one. For example after 25 possible directions it start becoming a High amount directions, and there for is indistinctive to a student to have 35, 40, 45 or 50 directions. We use a model based on the fuzzy logic to estimate the probability of educational path change for each student. Figures 2 and 3 present the types of the membership functions for this model divided into three scenarios. In terms of this model we take into account the functions of perspective directions of graduation for the students, the function of budget support possibility for each student, the function of expected salary level (Fig. 1).

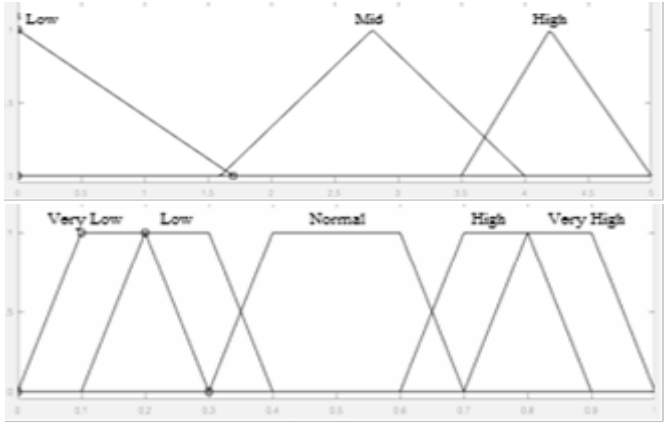

Fig. 2. Possible Salary Level and Probability of Educational Path Change membership functions

Based on these functions in terms of fuzzy logic we describe the function of educational path change (Fig. 2). According to the membership functions plots we have five scenarios, based to which we can describe the probability of educational path change from the very low to the very high probability.

For the probability of a student of getting a Budget support things are more equal, but the ranges overlap strongly, this means in that this variable influence more when the values are far away from the overlapping points. For the estimate that a student will earn a more analytical approach was used. Since there are not many jobs above 35000 roubles, for students who just finished university, this range is considered high and therefore is a small range in comparison to the other. For the low and mid ranges, a similar process was made. And for the output variable of the probability of change, 5 ranges were established, taking into account a big average range called “Normal” and other 4 equal ranges that overlap (Table 2).

Table 2. Possible Salary and Probability of Educational Path Change membership functions

Directions	Budget Support Possibility	Expected Salary	Possibility of Educational Path Change
Low	Low	Low	High
		Medium	Normal
		High	Very Low
	Medium	Low	Normal
		Medium	Low
		High	Very Low
	High	Low	Normal
		Medium	Low
		High	Very Low
Medium	Low	Low	Normal
		Medium	Normal
		High	Low
	Medium	Low	Normal
		Medium	Normal
		High	Low
	High	Low	Normal
		Medium	Normal
		High	Low
High	Low	Low	Very High
		Medium	High
		High	Normal
	Medium	Low	High
		Medium	Normal
		High	Normal
	High	Low	Normal
		Medium	Normal
		High	Low

This table shows the rules developed using an analytical understanding of the way a student make a decision upon the 3 input variables. For instance is a student has a HIGH amount of directions of changes, a LOW probability of getting budget support to his studies and his estimated salary is as MID (Average) the probability of changing of program is HIGH. During the modeling process we introduce ranges for the output variable, describing the probability of educational path change (Fig. 3). At the same time we introduce the main rules of the fuzzy model. The students' decision in terms of this model depends on the preferred educational direction, the budget support possibility and the expected salary level.

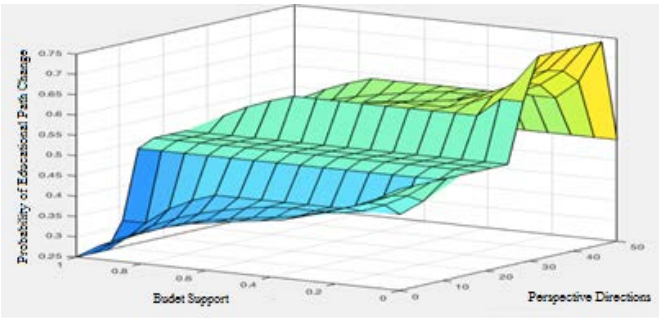

Fig. 3. Rules Surface

The Educational Path Change Probability is varied between very high (0.7<VH<1.0), high (0.6<H<0.9), normal (0.3<N<0.7), low (0.1<L0.4) and very low(0.0<VL<0.3) depending on the main model parameters. In terms of this model we also establish a set of rules for the students' decision for the educational path change. So, if the set of exams passes well for the educational path, the expected salary is high and there is a possibility of budget support, students won't change the current educational path. If the set of exams passes well for the educational path, but the expected salary is low and there is no possibility of budget support, students will search another educational path.

A part of the results obtained using fuzzy logic model are presented on figure 4. According to them 82% of all students have the possibility to change their educational path, but as shown in the model of educational paths optimization just in 31% of all cases it can be economically feasible for the students. According to table 1 the mostly optimal educational paths are in such fields of study, as Economics and Management, Public Administration and Entrepreneurship and Military Technical Education and Security.

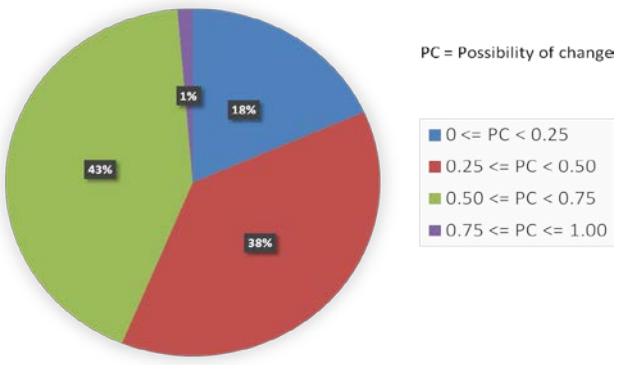

Fig. 4. Possibility of student's educational path change

4. CONCLUSION

The present model of individuals' choice of economically optimal educational paths has received approval and allows us to draw the following conclusions:

1. The research of economic incentives and motivation of individuals' choice has theoretical and practical significance.

2. Economic incentives have a significant influence on the choice of educational paths, and should be used as an advantage in educational policy in the planning the investment level in human capital.

3. The most important factors in determining the optimal educational paths are: the expected income after the graduation (22%), the reducing tuition fees or public subsidies (12%). There is no evidence of explicit dependence of the choice of the economically optimal education path on the progress of education.

4. A study on educational paths requires further improvement of the current economic model.

We believe that a model differentiation should be given a development priority. In this conditions we plan to extend social and personal characteristics of the analyzed individuals. New elements have to include direct characteristics, such as gender, age, progress in research and indirect assessment of personal qualities. We plan to expand the potential of the model analysis, adding the after-effects of selected education paths and cluster analysis of possible educational paths.

The fuzzy logic model allows the describing of educational path change probability. At the same time on the basis of this model it is possible to analyse the impact of student's choice on the economic sectors development. The Educational Path change probability in the current model is varied between five levels and depends on the amount of perspective directions of graduation for students, on the budget support possibility for each student and on the expected salary level after graduation. For the further research we plan to extend the model by analyzing individual's social and personal characteristics. New elements at the extended model have to include personal characteristics, such as gender, age, progress in research and indirect assessment of personal qualities. We plan to select these characteristics applying the methods of big data analysis. It is necessary to expand the potential of the model analysis, adding the after-effects of selected education paths and cluster analysis of possible educational paths. As the application of this approach we can estimate the probability of educational path change for each student and optimize the education process in the University. The combination of fuzzy logic models, optimization models and the search & matching model will allow the correction of educational process, depending on the labor market demand.

5. ACKNOWLEDGMENTS

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